U.S. Chemical Safety and Hazard Investigation Board

CSB Investigation of Natural Gas Explosion Kleen Energy, Middletown, CT Thomas Panel Meeting August 24, 2010

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Based on presentation by CSB Investigation Team
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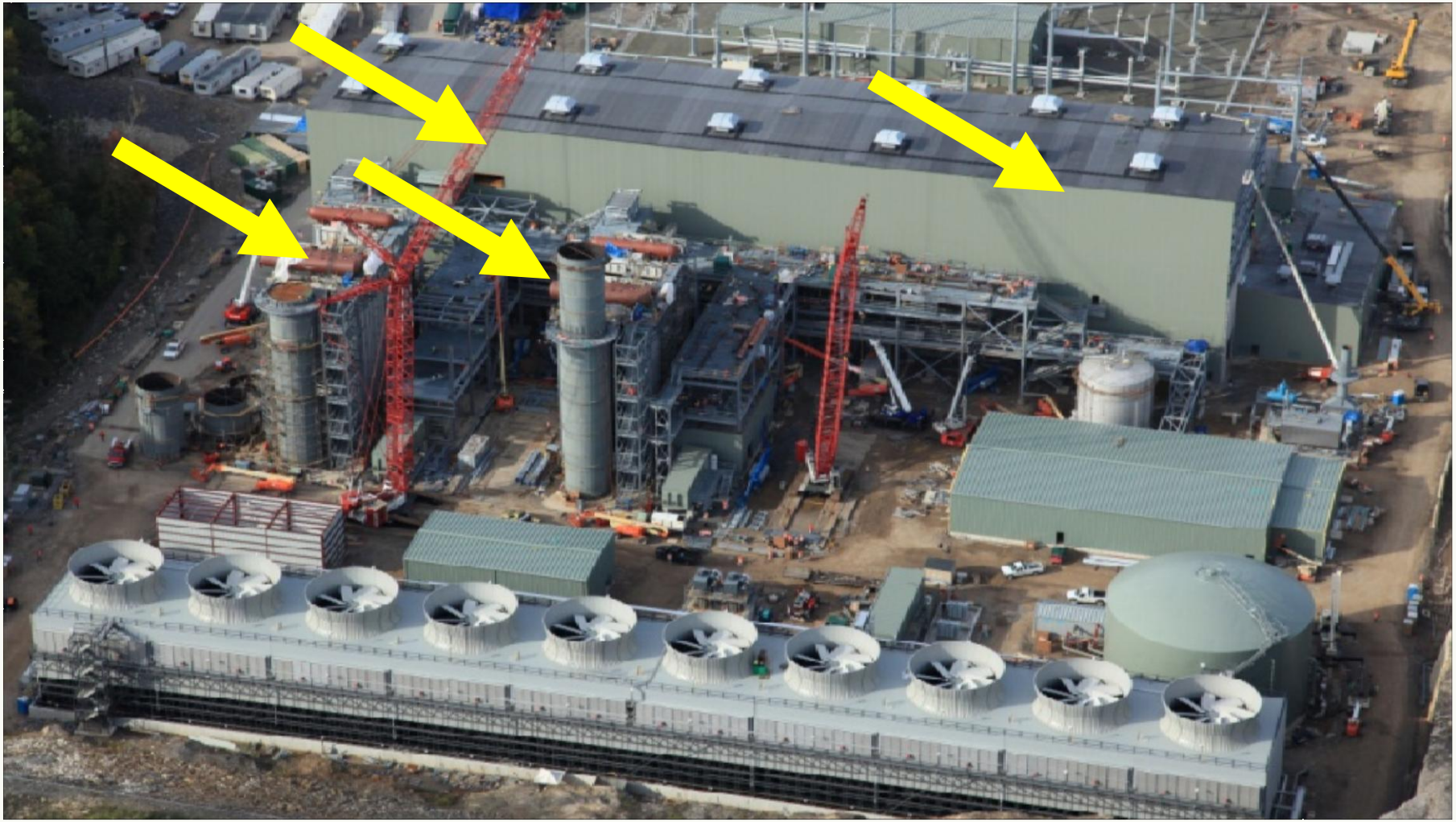
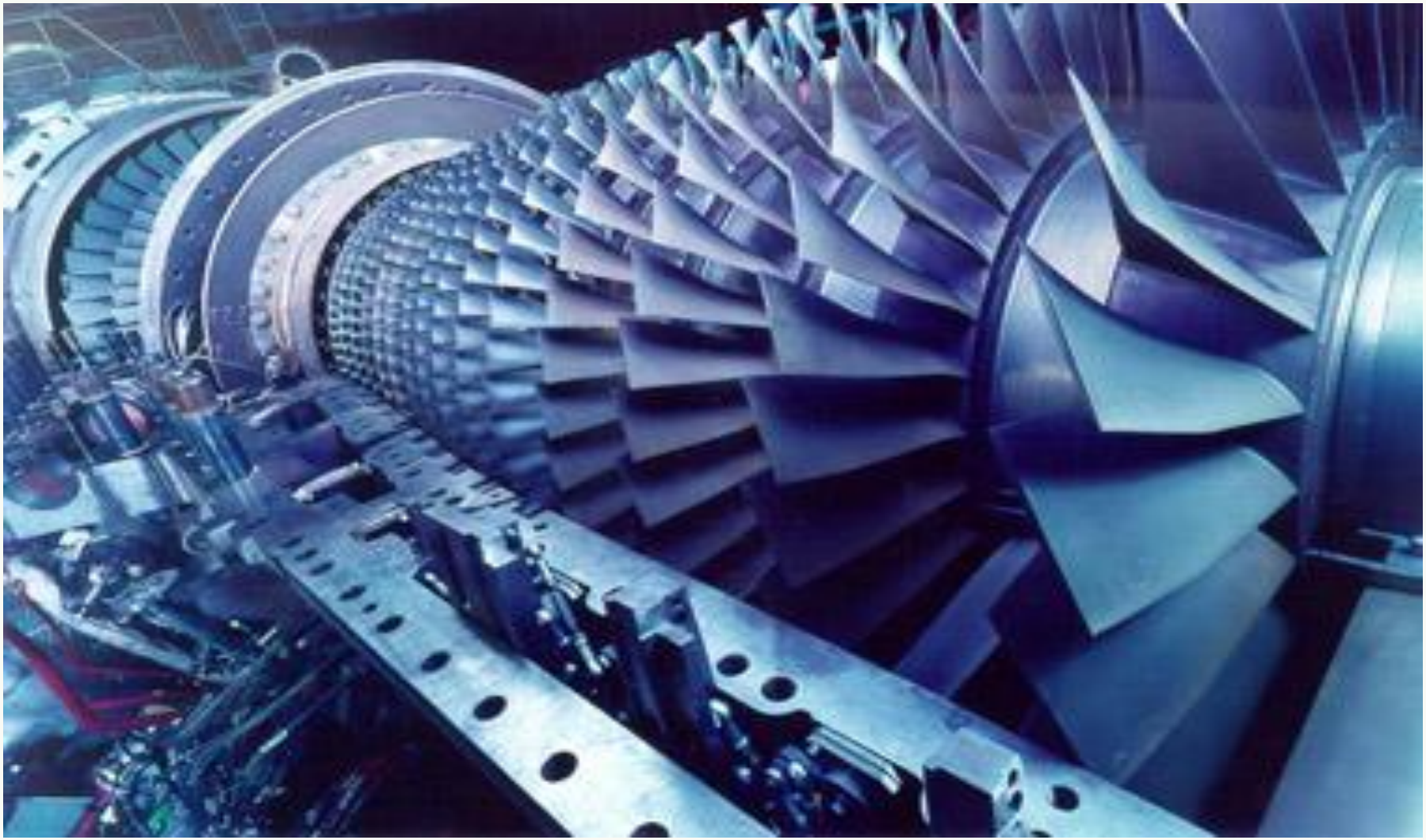
Brief Outline

- Description of Kleen Plant
- Incident Background
- Similar Incidents & Future Risks
- Alternative Pipe Cleaning Methods
- Codes, Standards, and Regulations
- Conclusions & Recommendations
- Recent Developments and Suggestions for Panel

Electricity Generated in Combined-Cycle Plant



Debris in Gas Can Damage Turbine Blades



http://www.dlr.de/en/Portaldata/1/Resources/portal_news/newsarchivstuttgart/kraftwerke_030306/AcrD_380h.jpg

Gas Blow Led to Explosion

- Piping cleaned of debris by "gas blow," a large volume of high pressure natural gas pushed through pipes
- Large quantity of flammable natural gas was released
- Explosion

15 Natural Gas Blows Were Performed the Morning of the Incident

Restricted Area Limited During Gas Blows

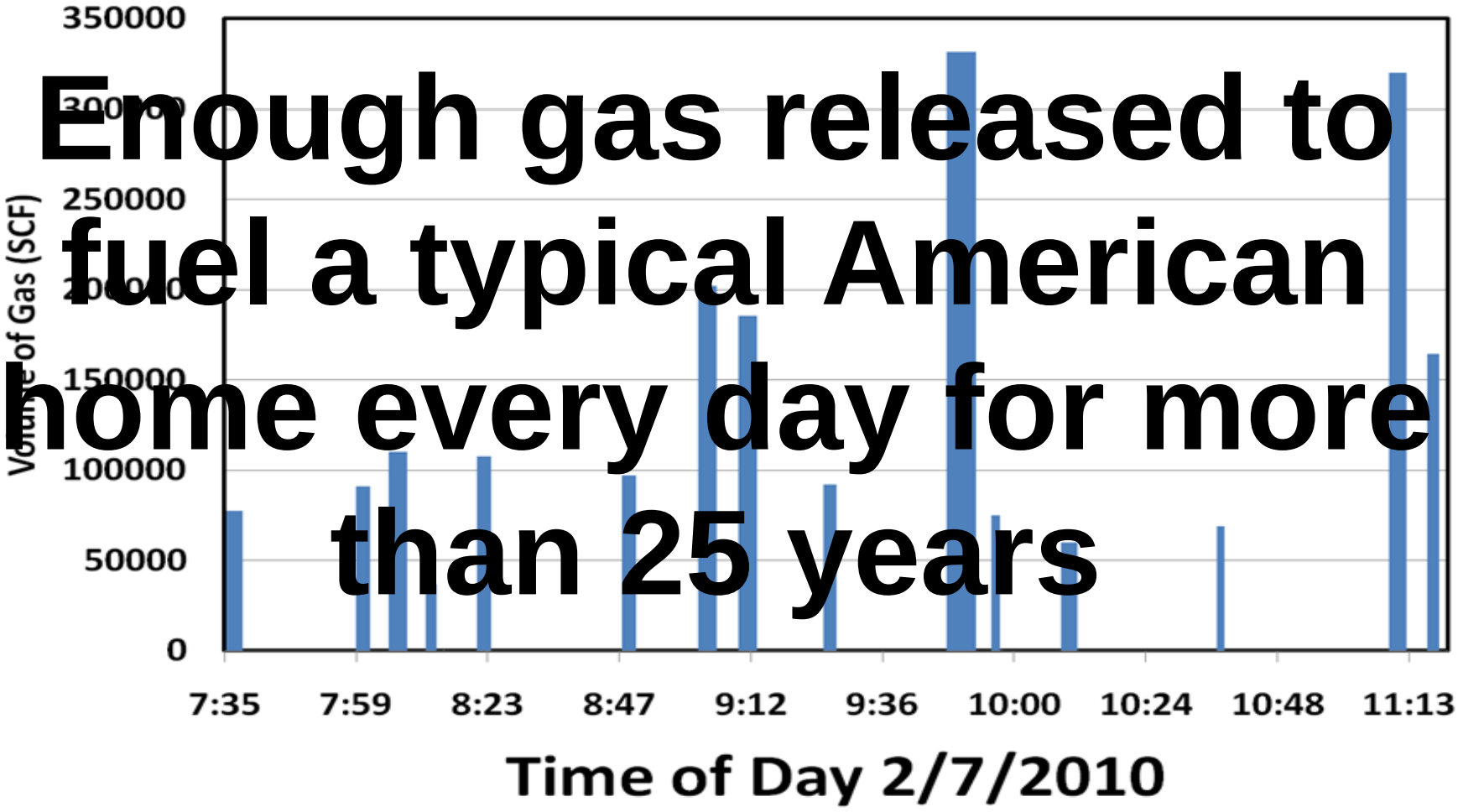
Many people were in the vicinity performing construction activities during the gas blows

Flammable Gas Cloud Caused Explosion

Consequences

- 6 Deaths
- Many injuries
- Significant damage to ~ $1 billion facility

Huge Volumes of Gas Released in "Blows"



Enough gas released to fuel a typical American home every day for more than 25 years

Multiple Ignition Sources Present

- **Ignition sources inside building**
  - Electrical power, welding, heaters)
- **Gas blow *itself* can be self-igniting**
  - Static electricity
  - Expelled metal debris striking surfaces
- **CSB did not determine the ignition source**
- **THE BEST WAY TO AVOID AN EXPLOSION IS TO AVOID THE RELEASE OF THE GAS**

Previous Gas Blow Incidents

Similar Fire at FirstEnergy

October 2001, Lorain, Ohio

- **Gas blow method used to clean fuel gas piping**
- **Gas unexpectedly ignited, causing a flame to shoot 30 to 40 feet into the air**
- **Gas blow was self igniting**
  - Metal debris struck nearby structure

Similar Explosion at Calpine

January 26, 2003, Fairfield, CA

– Explosion from a gas blow at Wolfskill power plant

Turbine Manufacturers Require Gas Cleanliness

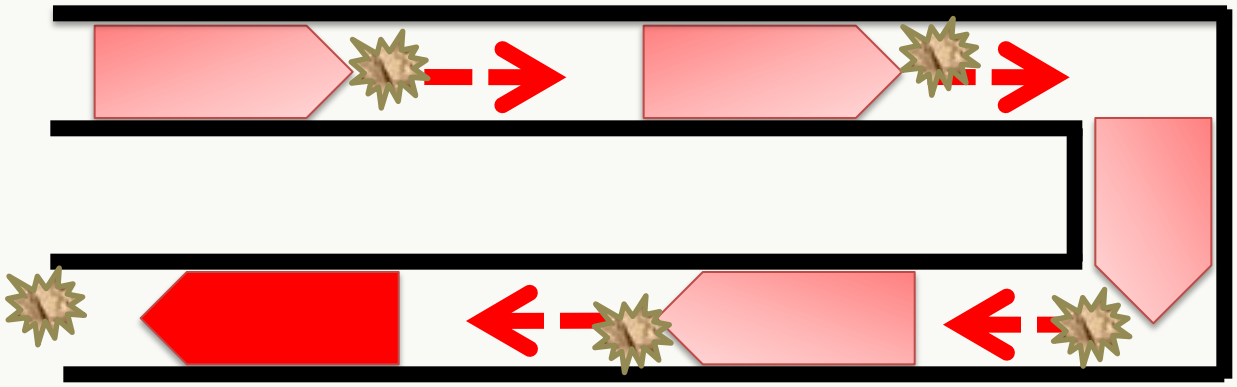
- **Target used to indicate cleanliness**
- **Turbine manufacturer representative often present during cleaning activities to verify pipe cleanliness**

Gas Turbine Manufacturer	Percentage of Plants Purchasing Turbines Between 2010 - 2015
GE	63%
Siemens	19%
Solar	11%
Mitsubishi	4%
Pratt & Whitney	1.5%
Rolls-Royce	1.5%

Platts World Electric Power Plants Database, 2010

Other Gas Pipe Cleaning Methods

- **Air and nitrogen blows**
  - **Perform exactly the same function as gas blows**
  - **Nitrogen is an asphyxiation hazard**
- **Pigging**

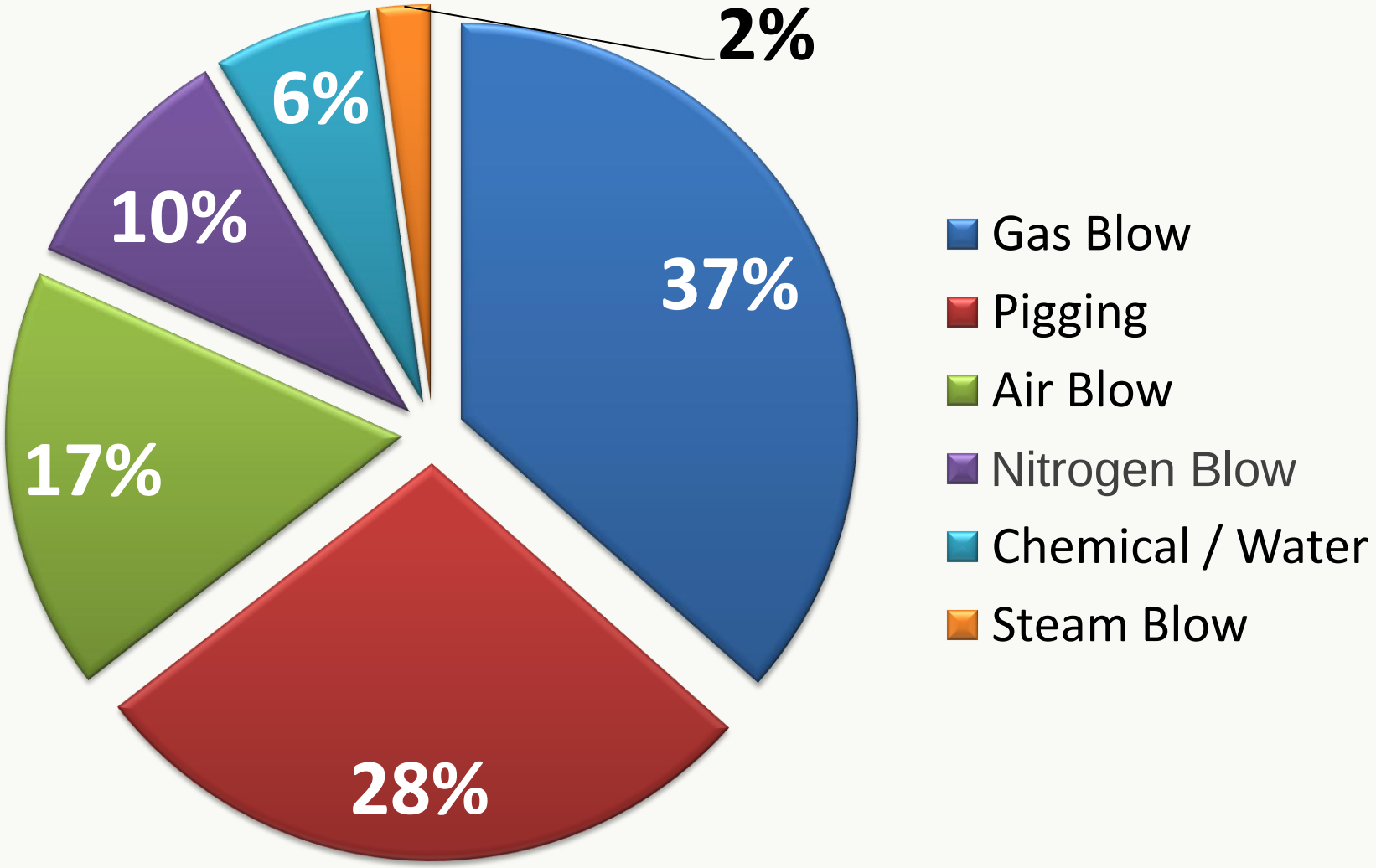


- **Steam blows, water or chemical cleaning**

Combined Cycle Survey Results

- **CSB conducted a survey with the assistance of the Combined Cycle Users Group**
- **CSB received 62 responses from Combined Cycle Users Group members**
- **63% indicated use of "Gas Blows"**
  - Only 1 indicated use of flare to safely destroy flammables

Safer Cleaning Alternatives are Common



Hazard Analysis and Control of Natural Gas Blows is Very Complicated

- **Requires technical evaluation of factors including:**
  - Amount of gas needed/used (Cleaning Force Ratio)
  - Height, location, and orientation of vent pipe
  - Velocity and density of discharging gas
  - Potential ignition sources
  - Personnel location
  - Wind speed & dispersion analysis
- **THESE FACTORS CAN BE SUBJECT TO GREAT UNCERTAINTY, *AND THEY ARE NOT NEEDED* FOR OTHER CLEANING METHODS, SUCH AS AIR BLOWS**

Review of Current Codes and Standards

NFPA Codes Provide No Guidance on Fuel Gas Pipe Cleaning

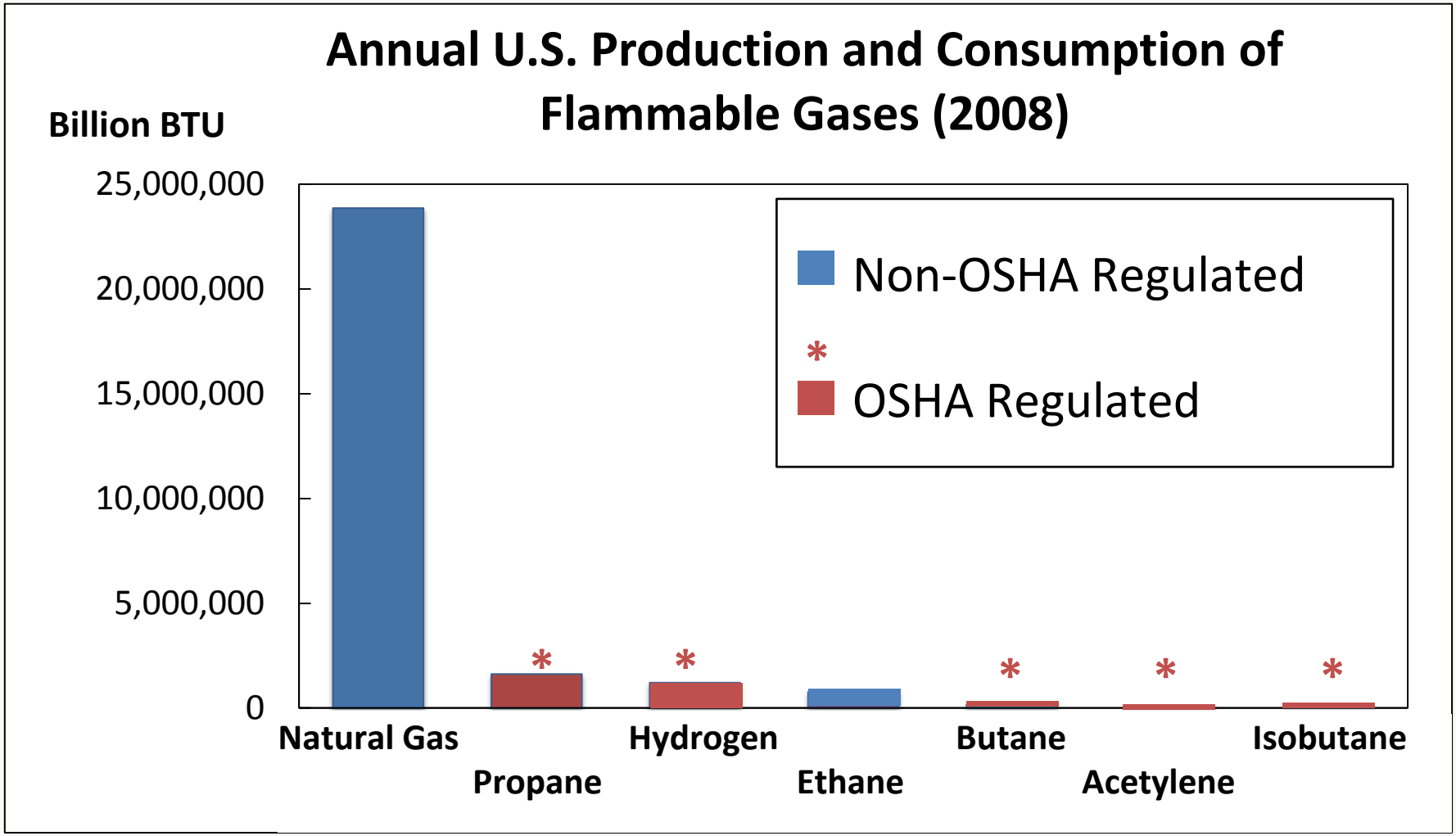
- **NFPA 54**
  - Does not address safe practices for cleaning fuel gas piping
  - Explicitly exempts fuel gas piping in power plants
- **NFPA 37**
  - Provides no guidance on how to clean gas piping without creating fire and explosion hazard
- **NFPA 850**
  - Does not address safe practices for cleaning fuel gas piping

Other Standards Do Not Prohibit Natural Gas Blows

- **ASME B31.1**
  - Does not prohibit natural gas blows
- **FM Global's "Natural Gas and Gas Piping"**
  - Allows for use of fuel gas to clean or test piping when the pressure is 0.5 psig or less

There are no standards and extremely limited guidance regarding safely cleaning fuel gas piping

OSHA Does Not Regulate Natural Gas Usage



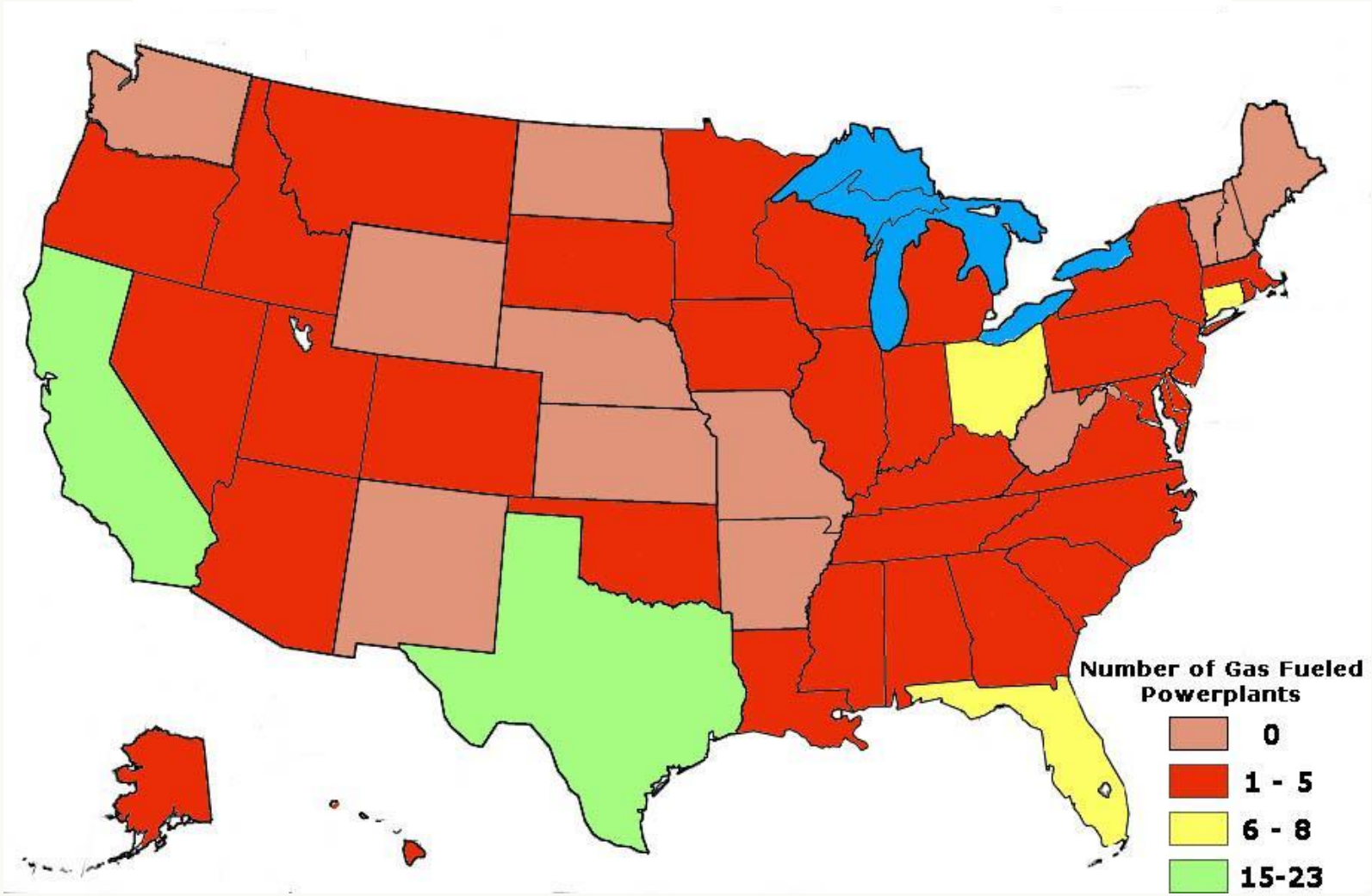
OSHA Regulations Contain Many Gaps

- **OSHA does not expressly prohibit the planned release of flammable gas in the vicinity of workers**
- **OSHA's PSM standard exempts flammable liquids or gases that are used solely for workplace fuel consumption**
- **OSHA does not require workers to participate in developing procedures or training related to fuel gas safety**

No Standards Specific to Power Generation Sector

- **The electric power sector and related industry associations currently:**
  - Do not operate a safety standards development program
  - Do not publish industry-recognized safety standards
  - Do not have recognized good practice safety standards or technical guidelines that address the cleaning of power plant fuel gas piping

Location Density of Future Gas Fueled Power Plants (2010-2015)



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Recommendations

Urgent Recommendation to OSHA

Promulgate regulations that address fuel gas safety for construction and general industry. At a minimum:

- **Prohibit the release of flammable gas to the atmosphere for the purpose of cleaning fuel gas piping**
- **Prohibit flammable gas venting or purging indoors. Prohibit venting or purging outdoors where fuel gas may form a flammable atmosphere in the vicinity of workers and/or ignition sources**

Urgent Recommendation to OSHA (continued)

- **Prohibit any work activity in areas where the concentration of flammable gas exceeds a fixed low percentage of the lower explosive limit (LEL) determined by appropriate combustible gas monitoring**
- **Require that companies develop flammable gas safety procedures and training that involves contractors, workers, and their representatives in decision-making**

Urgent Recommendation to National Fire Protection Association (NFPA)

Enact a Tentative Interim Amendment as well as permanent changes to the National Fuel Gas Code that addresses the safe conduct of fuel gas piping cleaning operations. At a minimum:

- **Remove the existing NFPA 54 fuel gas piping exemptions for power plants and systems with an operating pressure of 125 psig or more**
- **For the cleaning methodology, require the use of inherently safer alternatives such as air blows or pigging with air in lieu of the use of flammable gas**

Urgent Recommendation to American Society of Mechanical Engineers

Make appropriate changes to the 2012 version of *Power Piping*, ASME B31.1 to require the inherently safer fuel gas piping cleaning methodologies rather than natural gas blows. At a minimum:

- **For the cleaning or flushing methods discussed in B31.1 paragraph 122.10, require the use of inherently safer alternatives such as air blows and pigging with air as the motive force in lieu of the use of flammable gas**

Urgent Recommendation

Gas Turbine Manufacturers:

General Electric, Siemens, Solar, Mitsubishi Power Systems, Pratt & Whitney, and Rolls-Royce

Provide to your customers:

- **Comprehensive technical guidance on inherently safer methods for cleaning fuel gas piping, such as the use of air or pigging with air**
- **Comprehensive Cleaning Force Ratio (CFR) guidelines, specifying both the upper and lower limits required, to obtain satisfactory cleaning for the fuel gas piping for purposes of the warranties of the turbines**
- **Warnings against the use of fuel gas to clean pipes**

Proposed Urgent Recommendation

Gas Turbine Manufacturers:

General Electric, Siemens, Solar, Mitsubishi Power Systems, Pratt & Whitney, and Rolls-Royce

Work with the Electric Power Research Institute to publish technical guidance addressing the safe cleaning of fuel gas piping supplying gas turbines. At minimum:

- **For cleaning methodology, require the use of inherently safer alternatives such as air blows and pigging with air in lieu of flammable gas**

- **Provide technical guidance for the safe and effective use of alternative methods for cleaning such as air and pigging with air.**

Urgent Recommendation: Governor and Legislature of the State of Connecticut

- **Enact legislation applicable to power plants in the state that prohibits the use of flammable gas that is released to the atmosphere to clean fuel gas piping**

- **Adopt the current version of NFPA 54 as amended pursuant to our previous recommendation**

Proposed Urgent Recommendation

Electric Power Research Institute (EPRI):

Work with the six turbine manufacturers we identified to publish technical guidance addressing the safe cleaning of fuel gas piping supplying gas turbines. At minimum:

- **For the cleaning methodology, require the use of inherently safer alternatives such as air blows and pigging with air in lieu of the use of flammable gas.**
- **Provide comprehensive technical guidance on inherently safer methods for cleaning fuel gas piping, such as the use of air or pigging with air.**

RECENT IMPORTANT DEVELOPMENTS

•NFPA: new committee to develop comprehensive flammable gas standard in expedited manner

• International Code Council: Will consider modification of their code to incorporate CSB recommendations

• American Society of Mechanical Engineers: Starting review process for ASME B31.1.

• Four major turbine manufacturers develop guidance with firm warnings regarding hazards of natural gas "blows"

• OSHA: Describes natural gas "blows" as inherently unsafe, reports intention to study CSB recommendations carefully, but expresses concern about procedural and legal obstacles to action.

Conclusions

- **Natural gas "blows" are inherently unsafe and should be replaced by other available and feasible methods.**
- **CSB urges the Thomas Panel to recommend that the Connecticut State Legislature and Governor approve legislation consistent with the CSB recommendation.**

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Questions?